DOE/MC/08216-140

THE RELATIONSHIP BETWEEN PHOTOLINEAMENTS AND DEVONIAN SHALE GAS WELL PRODUCTIVITY; WITH APPLICATION TO TESTING OF DUPONT EL-836 EXPLOSIVE

By

A. P. Seskus

April 1981

Prepared for

UNITED STATES DEPARTMENT OF ENERGY
Morgantown Energy Technology Center
Morgantown, West Virginia

Under Contract No. DE-AM21-78MC08216

TECHNICAL INFORMATION CENTER
UNITED STATES DEPARTMENT OF ENERGY

DISCLAIMER

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A03
Microfiche A01

DOE/MC/08216-140
Distribution Category UC-92a

THE RELATIONSHIP BETWEEN PHOTOLINEAMENTS AND DEVONIAN SHALE GAS WELL PRODUCTIVITY; WITH APPLICATION TO TESTING OF DUPONT EL-836 EXPLOSIVE

by

A. P. Seskus

Science Applications, Incorporated

April 1981

Prepared for

UNITED STATES DEPARTMENT OF ENERGY
Morgantown Energy Technology Center
Morgantown, West Virginia

Under Contract No. DE-AM21-78MC08216

CONTENTS

TABLES

FIGURES

THE RELATIONSHIP BETWEEN PHOTOLINEAMENTS AND DEVONIAN SHALE GAS WELL PRODUCTIVITY; WITH APPLICATION TO TESTING OF DUPONT EL-836 EXPLOSIVE

by

A. P. Seskus[1]

ABSTRACT

An analysis of the relationship between Devonian Shale gas well productivity in Putnam County, WV and the orientation of, distance to, and density of the nearest photolineament (at scales of 1:32000 and 1:86000) was performed using primarily non-parametric statistical techniques. The results indicate that production is higher within 1300 feet of a low altitude photolineament. There is no association between the orientation of the lineament and productivity. Results on photolineament density are inconclusive. These results appear to be confirmed by the analysis of the DuPont EL-836 Explosive tests, which also indicate a statistically significant increase in open flow over conventional shooting.

[1]Staff Scientist, Science Applications, Inc., Morgantown, WV

INTRODUCTION

A previous study of production of Devonian Shale gas wells relative to photolineament locations by Howard, et al. (1979) in Perry County, Kentucky showed that cumulative production of gas wells within 300 feet of a low altitude (1:24000) photolineament is greater than the production of wells more than 300 feet from such a lineament. No significant effect was found for intermediate altitude (1:62500 and 1:250000) lineaments.

Other studies relating photolineaments to open flows of Devonian Shale gas wells have been reported. Werner (1977) concluded that in Jackson, Wayne and Marion counties, West Virginia, high final open flows "are apparently distributed without regard to photolineament location." However, this conclusion is based only on a visual inspection of overlaying open flow maps on lineament maps. Jones and Rauch (1978), in a study of the Cottageville field in Jackson County, found statistically significant higher initial open flows in wells within 0.5 miles of short photolineaments bearing N60^{o}W - N90^{o}W, and also found higher initial open flows in areas of higher lineament density.

Beebe (1979) extended the analysis of Jones and Rauch to portions of Putnam County, West Virginia. His statistical analysis found significantly higher initial and final open flows for wells within 0.4 km (approximately 1300 feet) of photolineaments oriented N60^{o}W - N30^{o}E, and also for wells in areas of high N60^{o}W - N30^{o}E photolineament density.

The objectives of this study were to:

- Determine if the results of Howard et al. were applicable to other areas.
- Determine if the relationship found by Beebe could be extended to production data, as well as open flow data.
- Provide assistance in selecting sites for a comparison test of standard "shooting" techniques and DuPont EL 836 explosive, such that the two groups would be equally favored by proximity to lineaments.

The next section gives details of data generation and methodology. Results are presented first for the relationship of lineaments to final open flow, followed by an analysis of the relationship to production data. Hypotheses derived from these results were then further tested using data on wells drilled as part of a test of DuPont El-836 explosive. These tests were performed as part of a contract with DOE on the Eastern Gas Shales Project (Contract No. DE-AC21-78MC11843).

METHODOLOGY

1. Data Generation

A lineament map (Figure 1) based on aerial photography at scales of 1:32000 and 1:86000 for the Bancroft and Elmwood quadrangles of Putnam County, West Virginia was provided by Howard and Associates, Inc.

Production data for 22 Devonian Shale gas wells was obtained and these wellls were plotted on the lineament map. Locations of additional wells in the area were obtained from work done by Beebe (1979). Final open flow data was available for all the wells.

The distance and orientation of the nearest lineament to each well was measured (Table 1), and contour maps drawn of final open flow (Figure 2), low altitude (1:32000) photolineament density (Figure 3), and intermediate altitude (1:86000) photolineament density (Figure 4). The wells used in the test of the DuPont explosive were not included in this phase of the study, since they had not yet been drilled. (The well locations are shown in Figures 1, 2, and 3, however) The photolineament density maps were obtained by covering the area with a square mile grid, measuring the length within each grid square of the lineament type, then plotting the resultant value (in miles/square mile) at the center of the square.

2. Statistical Data Analysis

The commonly used parametric tests ('t' test and 'F' test) assume populations with a normal distribution and equal variances. Previous studies of Devonian Shale gas wells (Pulle and Seskus, 1980, Howard et al. 1979) indicate that the cumulative production follows a lognormal distribution, and hence parametric tests can be used on the logarithm of production.

The statistical approach used in analyzing open flow data is non-parametric, i.e., no assumptions about the form or variance of the distributions of final open flow are made. Due to the lack of information on the distribution of final open flow of Devonian Shale wells, it was not felt that the use of parametric tests ('t' test and 'F' test) were justified. The tests used were: the Mann-Whitney test (replacing the 't' test), which has an efficiency close to 95% of the t-test for moderate sample sizes (Siegel, 1956); the Kruskal-Wallis analysis of variance (replacing the 'F' test), which has an asymptotic efficiency of 95.5% compared to the F test; and the X^2 test.

A significance level of .05 was used for all the statistical tests.

RELATIONSHIP OF LINEAMENTS TO FINAL OPEN FLOW

1. Orientation of Nearest Photolineament

The final open flows of wells within each of six 30^0 categories based on orientation of the nearest lineament, are shown in Figures 5 and 6, for low and intermediate altitude photolineaments, respectively.

The Kruskal-Wallis one-way analysis of variance was used to test the hypothesis that there is no difference in open flows as a function of the orientation of the nearest photolineament. The probability of the observed values of the H statistic calculated were

$p = 0.80$ low altitude lineaments

$p = 0.11$ intermediate altitude lineaments

It was thus concluded that there is no statistically significant effect of orientation of the nearest photolineament on final open flow.

2. Distance of Nearest Photolineament

The graphs of final open flow versus distance to the nearest lineament are shown in Figures 7 and 8. Inspection of these graphs indicates no obvious breakpoint between high and low open flow wells.

A) The number of wells within 300 feet of a lineament of either scale is shown below

Intermediate Altitude

(1:86000 Scale)

Low Altitude (1:32000 Scale)	<300	>300	
<300	1	18	N=19
>300	7	18	N=25
	N=8	N=36	N=44

The final open flows, and the median and mean values, are given for each category in Table 2.

The Kruskal-Wallis one-way analysis of variance was used to test the hypothesis that there is no difference in the average final open flows between wells in the 4 categories above.

The probability associated with the data was p=0.40, thus the hypothesis could not be rejected.

A Mann-Whitney test was then run comparing the final open flow of wells within 300 feet of an intermediate scale lineament with open flows of wells greater than 300 feet from such a lineament. No statistically significant difference was observed (p=0.40).

The Mann-Whitney test for low altitude lineaments gave a probability of p=0.07. Although not statistically significant (using a .05 significance leve), the difference between the two groups (less than 300 feet - and more - than - 300 feet from a low altitude photolineament) is in the expected direction.

B) A similar analysis was then performed, but using a distance of 0.4 km (approximately 1300 feet) as the cutoff, as used by Beebe in his study of Putnam County. The results are summarized below, and the final open flows in each category are given in Table 3.

		Intermediate Altitude (1:86000 Scale) <1300	Intermediate Altitude (1:86000 Scale) >1300	
Low Altitude (1:32000 Scale)	<1300	23	9	N=32
	>1300	12	0	N=12
		N=35	N=9	N=44

Kruskal-Wallis test of overall significance p=.5
Mann-Whitney U test for intermediate altitude lineaments p=.14
Mann-Whitney U test for low altitude lineaments p=.004

It thus appears that the final open flow of gas wells within 1300 feet of a low altitude photolineament is higher than the final open flow of wells more than 1300 from such a lineament.

3. <u>Photolineament Density</u>

To determine if there is a relationship between photolineament density and final open flows, an orthogonal grid with a 2000 foot spacing was constructed, and the open flows and photolineament density at each grid intersection point were determined, as in Beebe (1979). This technique eliminates the bias that is present if actual well locations are used, since successful well locations do not form a random sample of the area.

The number of points in various categories of open flow and lineament density is given in Table 4 for low altitude lineaments and in Table 5 for intermediate altitude lineaments. These tables were analyzed using the χ^2 test, and the results are shown below.

Low Altitude Photolineaments

Final Open Flow (MCFD)

Photolineament Density (miles/mile^2)

	<200	>200
<1	26	5
>1	25	38

$\chi^2 = 14.6$

$p < 0.001$

Significant

	<200	>200
<2	34	12
>2	17	31

$\chi^2 = 12.5$

$p < 0.001$

Significant

	<200	>200
<3	40	3
>3	11	10

$\chi^2 = 0.003$

$p = 0.5$

Not Significant

Intermediate Altitude Photolineaments

Final Open Flow (MCFD)

Photolineament Density (miles/mile^2)

	<200	>200
<1	1	14
>1	46	29

$\chi^2 = 12.9$

$p < 0.001$

Significant

	<200	>200
<2	15	31
>2	32	12

$\chi^2 = 12.9$

$p < 0.001$

Significant

	<200	>200
<3	39	40
>3	8	3

$\chi^2 = 1.3$

$p = 0.12$

Not Significant

Final Open Flow (MCFD)

Photolineament Density (miles/mile^2)

	<300	>300
<1	6	9
>1	65	10

$\chi^2 = 1.37$

$p = 0.1$

Not Significant

	<300	>300
<2	28	18
>2	43	1

$\chi^2 = 16.2$

$p < 0.001$

Significant

	<300	>300
<3	60	19
>3	11	0

$\chi^2 = 2.06$

$p = 0.07$

Not Significant

The above results indicate significantly higher open flows for wells in areas of high density of low altitude photolineaments, but low density of intermediate altitude lineaments.

RELATIONSHIP OF LINEAMENTS TO PRODUCTION

Monthly production data (for 3 to 10 months) was available for 19 wells in the study area. The average daily production (a) during the first three months (b) for the whole period available (variable from 3 to 10 months), was calculated for each well (Table 6). The correlation between these two quantities was 0.98. In all subsequent analyses, the average daily production during the first three months was used.

Of these 19 wells, five (863, 865, 867, 868, 871) were shot only in the black shale interval, the remaining fourteen being shot in both the black and gray shales. The mean production of these five wells was 44 MCFD, compared to a mean of 68 MCFD for all nineteen wells.

This difference was not taken into account in the following analysis. Since four of the five wells were within 300 feet of a low altitude photolineament, any significant results would become even more significant if this effect was incorporated. There is no overall difference between these two groups of wells with respect to photolineament density, so any conclusions in this area will not be affected.

The correlation between this production measure and final open flow was 0.85. The biggest difference in individual wells was well 865, which was ranked 17th on open flow, but 9th on production.

Histograms of production were plotted, both for the actual production and for its logarithm (Figures 9 and 10). These indicated a lognormal distribution, as has been found for cumulative production over longer time periods.

1. Orientation of Nearest Photolineament

For low altitude photolineaments, an analysis of variance on the logarithm of production was performed. The F-value was .148, with an associated probability under the null hypothesis of 0.9.

For intermediate altitude lineaments, a 't' test was used, since all but two wells fell into one of two classes. The probability for the observed 't' value of 0.69 was 0.25.

The above results indicate no significant effect of orientation of the nearest photolineament (low or intermediate altitude) on production, confirming the results based on open flow data.

2. Distance to Nearest Photolineament

A.) Based on a 't' test of the means the production (80 MCFD) of wells within 300 feet of a low-altitude photolineament was significantly higher than the mean (41 MCFD) of wells at a distance of more than 300 feet. The observed 't' value was 2.5, with probability P<.01 of occurring by chance.

There were no wells in this sample less than 300 feet from an intermediate altitude photolineament.

The open flow data showed the same trend, but the difference between the two groups was not statistically significant.

B.) Since no wells were more than 1300 feet from a lineament of both scales, a two-way analysis of variance with study of interactions was not possible.

A one-way analysis of variance for the effect on production of being within 1300 feet of lineaments of each scale found no overall significant effect. The analysis of variance results are given below. The mean production of the 3 cases were:

(a) Within 1300 feet of a lineament of each scale: 76 MCFD

(b) Within 1300 feet of a low-altitude lineament and more than 1300 feet from an intermediate altitude lineament: 71 MCFD

(c) More than 1300 feet from a low altitude photolineament, and less than 1300 feet from an intermediate lineament: 35 MCFD

	DF	SS	MS	F	Prob>F
Mean	1	312.4			
Treatments	2	.967	.484	1.6	.25
Error	16	4.74	.296		
Total	19	318.1			

Although no overall significant effect was found, 't' tests were used to examine separately the effect of each lineament scale.

There was a significant effect of low altitude photolineaments (using a distance of 1300 feet) on production, but no significant effect for intermediate altitude lineaments.

These results all correspond with those obtained using final open flow data.

3. Photolineament Density

Using the same technique as for open flow data (χ^2 test on 2-way frequency table of photolineament density and average production), but with actual wells instead of intersection points on a grid, no statistically significant effect was found, for either type of lineament. The data is shown in Table 7.

Summarizing the results of the previous sections within the area of Putnam County studied,

1. There is no significant effect of the orientation of photolineaments on the final open flow or average daily production of Devonian Shale gas wells.

2. The distance to the nearest low altitude photolineament has a significant effect on both open flow and production. Final open flows are higher for wells within 1300 feet of such a lineament and production is higher for wells within 300 feet.

3. Photolineament density appears to have an effect on final open flows, with high low altitude lineament density, and low intermediate altitude photolineament density, being favorable.

   Based on a smaller sample, no relationship between photolineament density and production was found.

EXPERIMENTAL TEST OF THE EFFECT OF PHOTOLINEAMENTS

As part of contract DE-AC21-78MC11843 under the Eastern Gas Shales Project, nine wells were drilled in Putnam County, WV, and treated: with conventional shooting (3 wells); a new DuPont explosive EL-836 (5 wells); and one under-reamed well.

The basic data for these wells on proximity to lineaments and final open flow is given in Table 8. Full information on low altitude photolineaments was available for 5 of the 9 wells.

A test of the overall significance of the difference between the final open flows of the three groups (conventional, normal duPont, under-reamed duPont) using the Kruskal-Wallis one-way analysis of variance by ranks indicated that there is a significant overall difference ($p<.01$).

Comparisons between the 3 conventional wells and the 5 wells stimulated with the normal size duPont explosive were performed using both parametric ('t'-test on logarithm of open flows, since the final open flows appear are lognormally distributed in Putnam County) and non-parametric (randomization test) tests. In both cases, a statistically significant difference was found.

$t = 2.60 \quad p <.05 \quad df = 4$

Randomization test: $p <.05$

The previous sections indicated significantly higher open flows
(a) for wells within 1300 feet of a low altitude photolineament
(b) in areas of high density of low altitude photolineaments

Table 9 shows the division of the wells on the basis of favorable or unfavorable values of the above two criteria. Both treatments appear similar on the first criterion but the DuPont treatment appears favored on the basis of lineament density. However, the best well (DuPont under-reamed case) is unfavorably located both on distance and density of lineaments. Figures 2, 3, and 4 indicate the location of the 9 wells on the lineament density and final open flow contours.

If the 8 wells (excluding the under-reamed case) are assumed to be similar treatments, then they can be combined into one sample for testing the two criteria previously developed for predicting open flows (distance and density of low altitude photolineaments). The results are:

Within 1300 Feet		Greater than 1300 Feet
	201 192 80 91	107 41
Median	142	74
	Density >2 mi./mi.^{2}	Density <2 mi./mi.^{2}
	201 192 91	80
Median	192	80

These differences, although large and in the expected direction, are not statistically significant (using the randomization test): However, the sample sizes are extremely small.

SUMMARY AND CONCLUSIONS

1. There is a significant association between Devonian Shale gas productivity (both average daily production and final open flow) and the distance to the nearest low-altitude photolineament.

   The average production was found to be higher for wells within 300 feet of such lineaments, and the final open flows were higher within 1300 feet.

2. There is no association between the orientation of the nearest photolineament and gas productivity.

3. Results on photolineament density are inconclusive. Significant effects were found using final open flow, but not when average daily production was used. However, the sample size for production (19) was much less than that used for open flows (90).

4. These results appear to be confirmed by the analysis of the nine well programs testing DuPont EL-836 explosive. EL-836 was found to give a statistically significant increase in final open flow over conventional shooting.

ACKNOWLEDGEMENTS

The author would like to acknowledge the help of E. I. duPont for providing well location maps and production data, the work of Jim Howard of Howard and Associates, Owensboro, Kentucky for the photolineament interpretation and the technical assistance of C. A. Komar, Project Manager, Eastern Gas Shales, DOE-Morgantown for making this study possible.

REFERENCES

1. Beebe, Robert R. (1979). A Study of Hydrogeologic Trends in Exploration for Devonian Shale Gas in the Midway-Extra Gas Field of Putnam County, West Virginia. Report prepared under DOE contract DE-AC21-76MC05194.

2. Howard, J. F., Lahoda, S. J., Zirk, W. E., and Komar, C. A. (1979). Gas Production of Devonian Shale Wells Relative to Photolineament Locations: A Statistical Analysis. METC/CR-79/28.

3. Jones, D. S. and Rauch, H. W. (1978). Lineaments and Groundwater Quality as Exploration tools for Groundwater and Gas in the Cottageville Area of West Virginia. Paper presented at the Second Eastern Gas Shales Symposium.

4. Pulle, C. V. and Seskus, A. P. Quantitative Analysis of the Economically Recoverable Resource. Final Report on Task Order 15 of Contract DE-AT21-78MC08216.

5. Seigel, S. 1956). Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill Kogakusha, Tokyo.

6. Werner, E. (1977). Application of Remote Sensing Studies to the Interpretation of Fracture Systems and Structural Styles in the Plateau Regions of Eastern Kentucky, Southwestern Virginia, and Southwestern West Virginia for Application to Fossil Fuel Extraction Processes. Final Report under DOE contract EY-76-S-21-8041.

Table 1 - Distance and Orientation of Nearest Photolineaments

Well No.	Low Altitude Photolineaments		Intermediate Altitude Photolineaments		Final Open Flow
	Distance (feet)	Orientation	Distance (ft.)	Orientation	
538	1000	N55°E	100	N40°W	211
586	2100	N59°E	290	N42°E	103
604	0	N59°E	600	N18°W	60
607	1100	N55°E	400	N47°E	198
618	400	N18°W	350	N41°W	73
621	720	N55°E	250	N18°W	189
629	1300	N55°E	200	N47°E	246
630	3130	N55°E	330	N42°E	84
632	1800	N18°W	0	N55°E	207
634	2000	N18°W	900	N68°E	61
635	1300	N61°E	2200	N45°E	231
637	3800	N83°E	910	N68°E	60
641	3300	N16°W	800	N18°W	57
642	3100	N73°E	120	N33°E	43
647	4200	N61°E	100	N42°E	273
653	2700	N61°E	590	N46°E	169
808	0	N19°W	280	N34°W	179
815	890	N16°W	730	N33°E	163
824	180	N18°W	310	N52°E	329
828	500	N56°E	1600	N46°E	82
829	150	N59°E	2000	N52°E	350
833	1300	N63°E	430	N45°E	270
861	1580	N53°E	720	N67°E	155
862	250	N17°W	600	N67°E	200
863	100	N17°W	420	N40°W	155
865	200	N62°E	1400	N44°E	120
866	290	N31°E	4200	N42°E	340
867	290	N27°W	1300	N52°E	175
868	1480	N37°E	500	N52°E	120
869	0	N42°E	2600	N43°E	260
870	200	N37°E	1150	N52°E	395
871	150	N61°E	2100	N34°E	85
873	250	N61°E	1300	N38°E	255
874	880	N55°E	1300	N45°W	170
875	0	N27°W	3400	N53°W	280

Table 1 - Distance and Orientation of Nearest Photolineaments (Continued)

Well No.	Low Altitude Photolineaments		Intermediate Altitude Photolineaments		Final Open Flow
	Distance (feet)	Orientation	Distance (ft.)	Orientation	
904	190	N37°E	870	N53°W	120
910	520	N6°E	1180	N50°W	200
911	380	N6°E	600	N53°W	305
921	2200	N61°E	450	N33°E	192
922	310	N21°W	1200	N50°W	240
923	0	N70°E	420	N53°W	350
926	200	N6°E	1800	N50°W	180
927	0	N72°E	1300	N60°W	130
928	120	N49°E	310	N60°W	102

Table 2 - Final Open Flow For Wells Within And Further Than 300 Feet From A Lineament of Either Scale

Low Altitude	Intermediate Altitude <300 Feet	Intermediate Altitude >300 Feet
<300 Feet	179 Mean = 179 Median = 179	200 395 180 155 85 130 120 255 102 340 280 350 175 120 329 260 350 60 Mean = 216 Median = 190
>300 Feet	211 103 246 189 273 207 43 Mean = 182 Median = 207	155 73 231 120 82 61 170 270 60 192 84 57 200 198 305 163 240 169 Mean = 157 Median = 166

Table 3 - Final Open Flow For Wells Within And Further Than 1300 Feet (0.4 km) From A Lineament Of Either Scale

Intermediate Altitude

Low Altitude	<1300			>1300
<1300 Feet	200	350	189	120
	155	130	163	340
	175	102	179	260
	395	73		85
	255	329		280
	170	60		180
	120	211		350
	200	270		82
	305	198		231
	240	246		
	Mean = 205			Mean = 214
	Median = 198			Median = 231
>1300 Feet	155	169		
	120	207		
	192	61		
	103	60		
	84	57		
	273	43		
	Mean = 127			
	Median = 112			

Table 4 - Frequency of Grid Points In Categories Of Final Open Flow And Low Altitude Photolineament Density

Low Altitude Photo-lineament Density (miles/mile^2)	Final Open Flow (MCFD) 0 - 100	100 - 200	200 - 300	300 - 400
0 - 0.5	2	3	1	0
0.5 - 1	4	17	4	0
1 - 2	2	6	7	0
2 - 3	1	5	9	12
>3	0	11	7	3

Table 5 - Frequency of Grid Points in Categories Of Final Open Flow And Intermediate Altitude Photolineament Density

Intermediate Altitude Photolineament Density (miles/mile^2)	Final Open Flow (MCFD) 0 - 100	100 - 200	200 - 300	>300
0 - 0.5	0	0	3	1
0.5 - 1	0	1	2	8
1 - 2	4	10	8	9
2 - 3	5	19	8	1
>3	2	6	3	0

Table 6 - Average Daily Production Data

Well No.	Final Open Flow (MCFD)	Rank	Average Daily Production 3 Months (MCFD)	Average Daily Production (All Data)	Months	Rank 3 Mo.	Rank All Data
861	155	5.5	42	44	10	[illegible]	8
862	200	10.5	62	56	7	12	13
863	155	5.5	49	49	3	9	9
865	120	3	57	52	10	11	11
866	340	17	98	89	8	15	15
867	175	7	51	51	3	10	10
868	120	3	29	25	10	2	2
869	260	14	85	66	10	14	14
870	395	19	181	136	10	19	19
871	85	1	35	33	7	3.5	5
873	255	13	109	91	7	16	16
875	280	15	113	105	8	17	17
904	120	3	28	23	10	1	1
910	200	10.5	36	31	7	5.5	3
911	305	16	65	53	10	13	12
921	192	9	35	33	7	3.5	5
922	240	12	38	35	4	7	7
923	350	18	139	116	9	18	18
926	180	8	36	33	4	5.5	5

Table 7: Average Daily Production (MCFD) of Wells in Various Photolineament Classes

Low Altitude / Intermediate Altitude		Lineament Density (mi/sq mi)			Mean
		0-2	2-3	3+	
Lineament Density (mi/sq mi)	0-1	139	113	98 36	97
	1-2	35 109	29 181 36 65	51 85 28 38	66
	2+	42 62 35	57	49	49
Mean		70	80	55	68

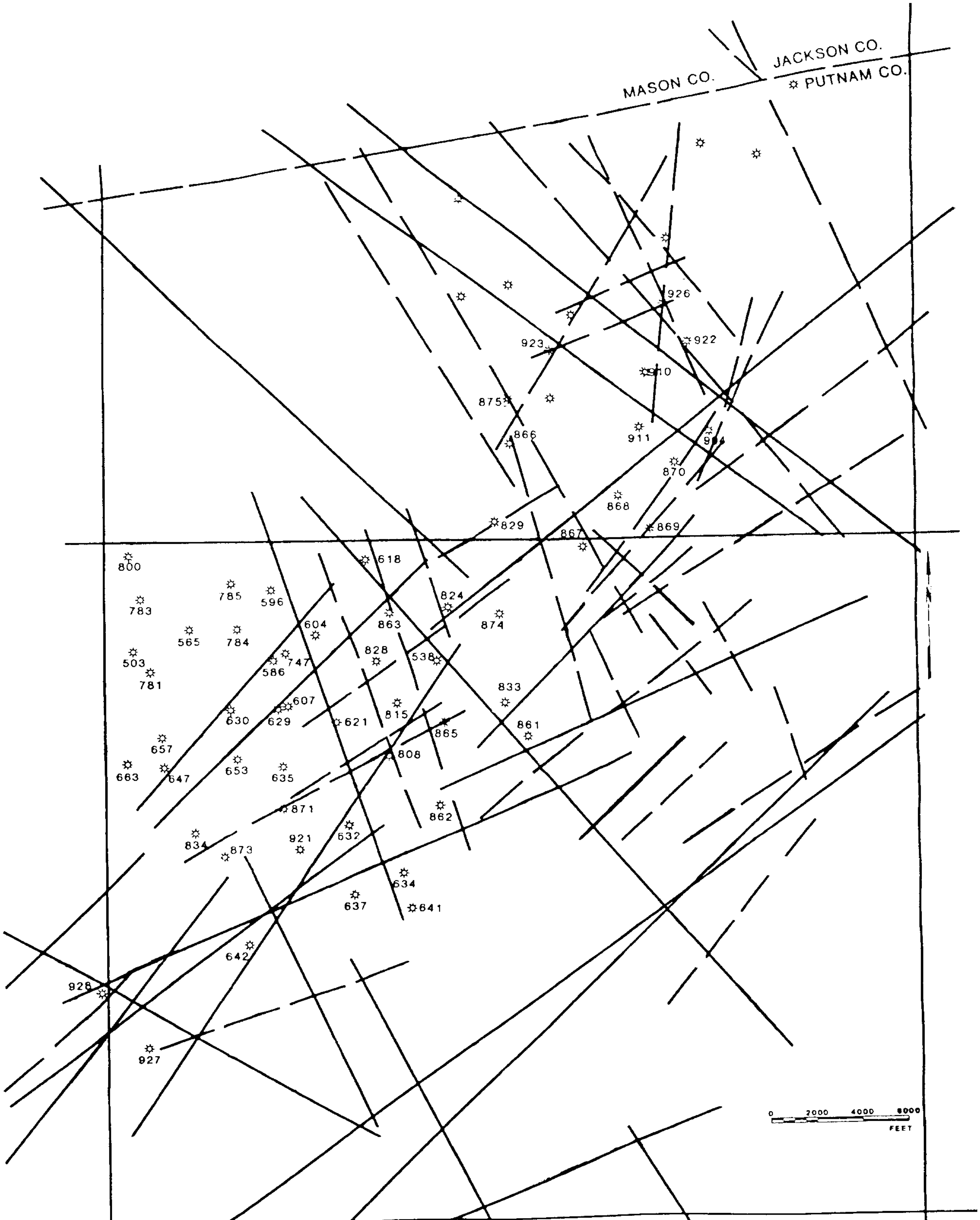
Table 8: Photolineament and Flow Data for Test Wells

Well No.	Low Altitude		Intermediate Altitude		Final Open Flow
	Density (mi/mi^2)	Distance to Nearest (ft)	Density (mi/mi^2)	Distance to Nearest (ft)	
Control:					
A32	1-2	400	<1	800	80
A44	NA	1400	NA	NA	41
A52	NA	NA	NA	NA	73
DuPont:					
A24	2-3	800	<1	2300	201
A25	>3	0	<1	4100	192
A31	NA	3100	NA	150	107
A45	NA	NA	NA	1600	89
B15	2-3	150	<1	1200	91
Under-Reamed:					
A26	1-2	2400	1-2	700	297

Table 9: Categorization of Test Wells

Distance to Nearest Low Altitude Photolineament (feet)	Final Open Flow (MCFD)		
	Conventional	Normal DuPont	Under-Reamed DuPont
<1300	80	201 192 91	
>1300	41	107	297
NA	73	89	

Density of Low Altitude Photo-lineaments	Final Open Flow (MCFD)		
>2 mi/mi^2		201 192 91	
<2 mi/mi^2	80		297
NA	41 73	107 89	



Taken from photo scale of 1:32000

Taken from Photo scale of 1:86000

FIGURE 1: Map of Study Area Showing Lineaments and Gas Well Locations

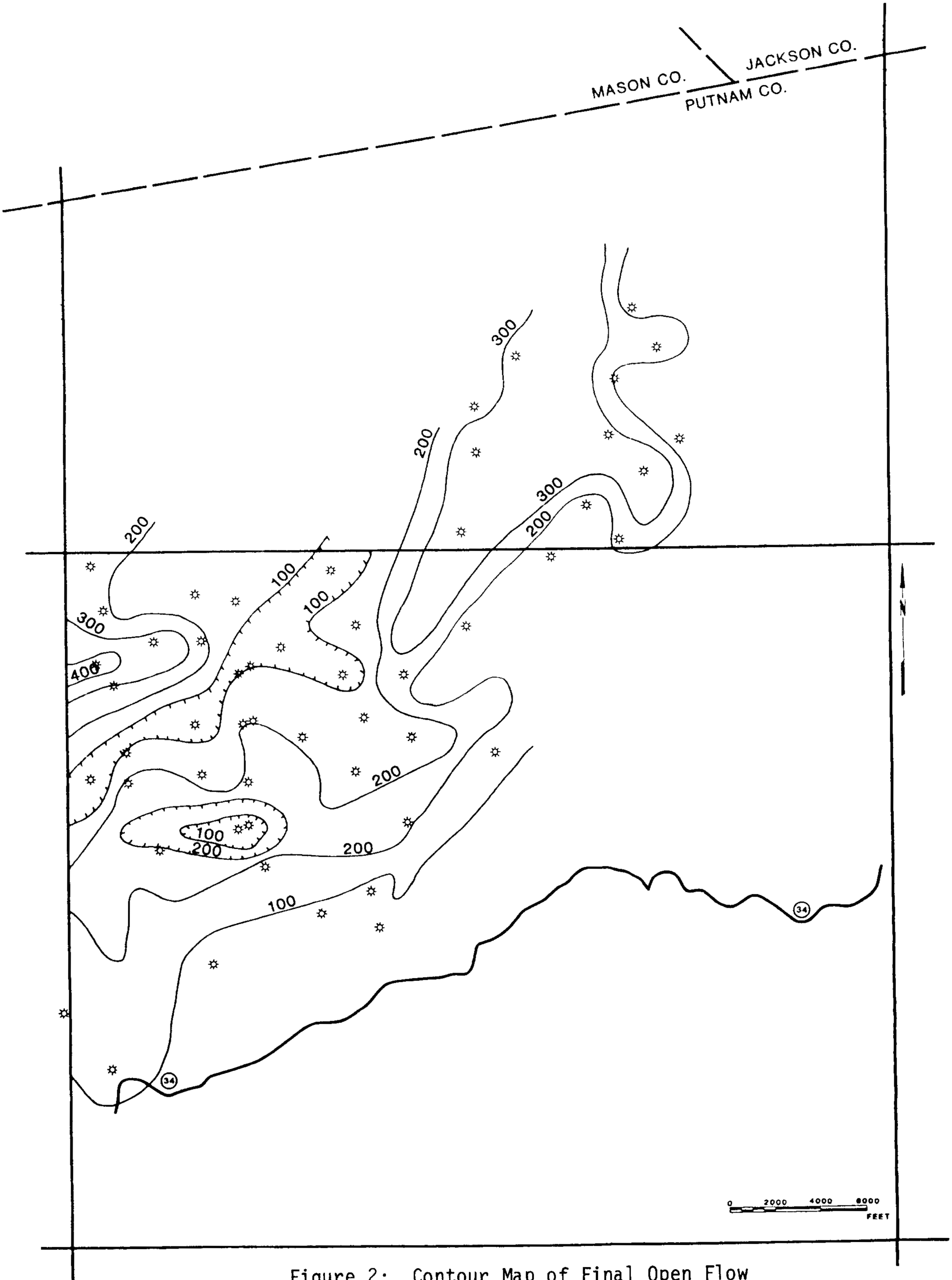


Figure 2: Contour Map of Final Open Flow (MCFD)

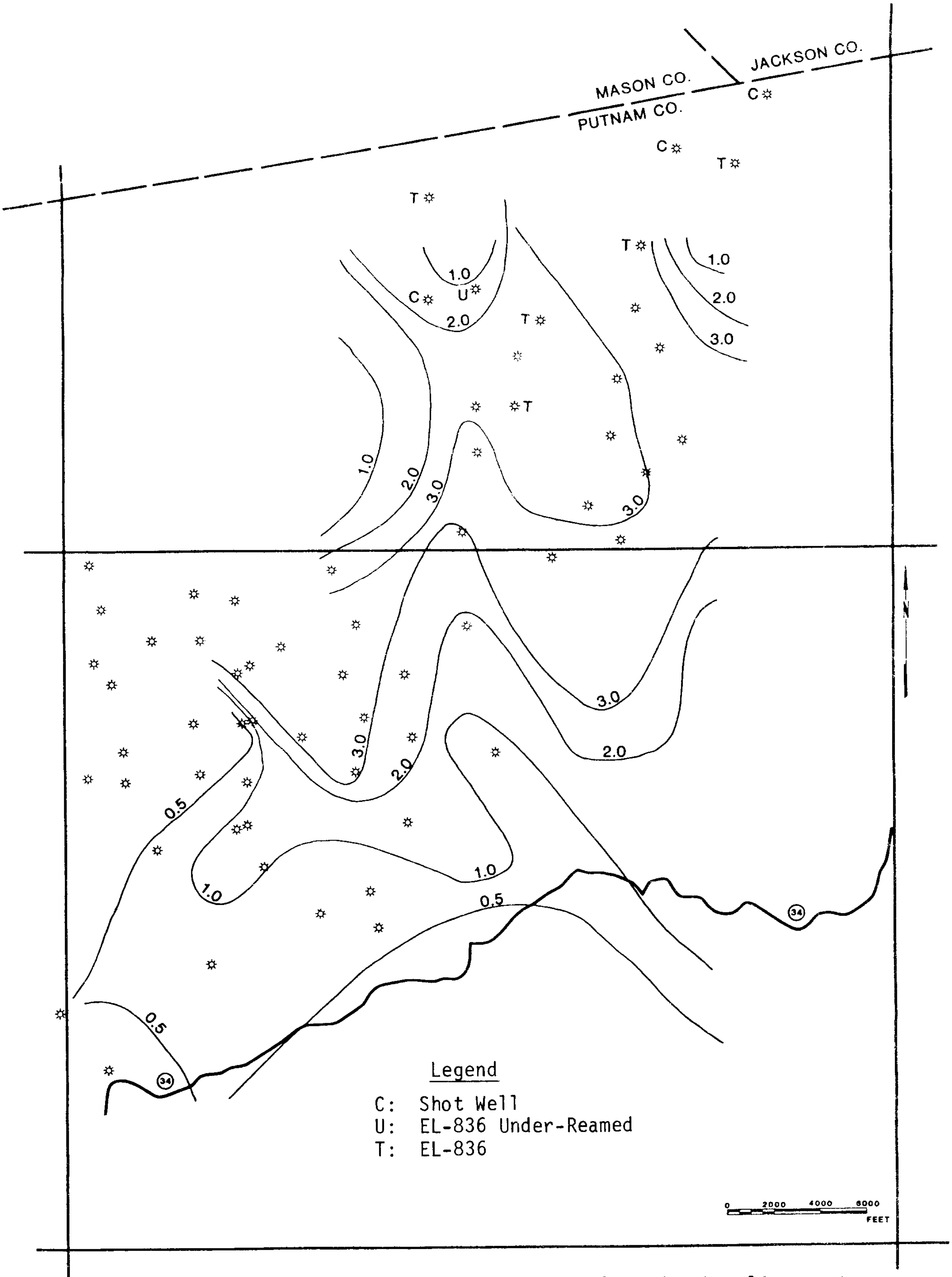


Figure 3: Contour Map of Density of Low Altitude Photolineaments (Miles/Mile^2) (1:32000 scale photography)

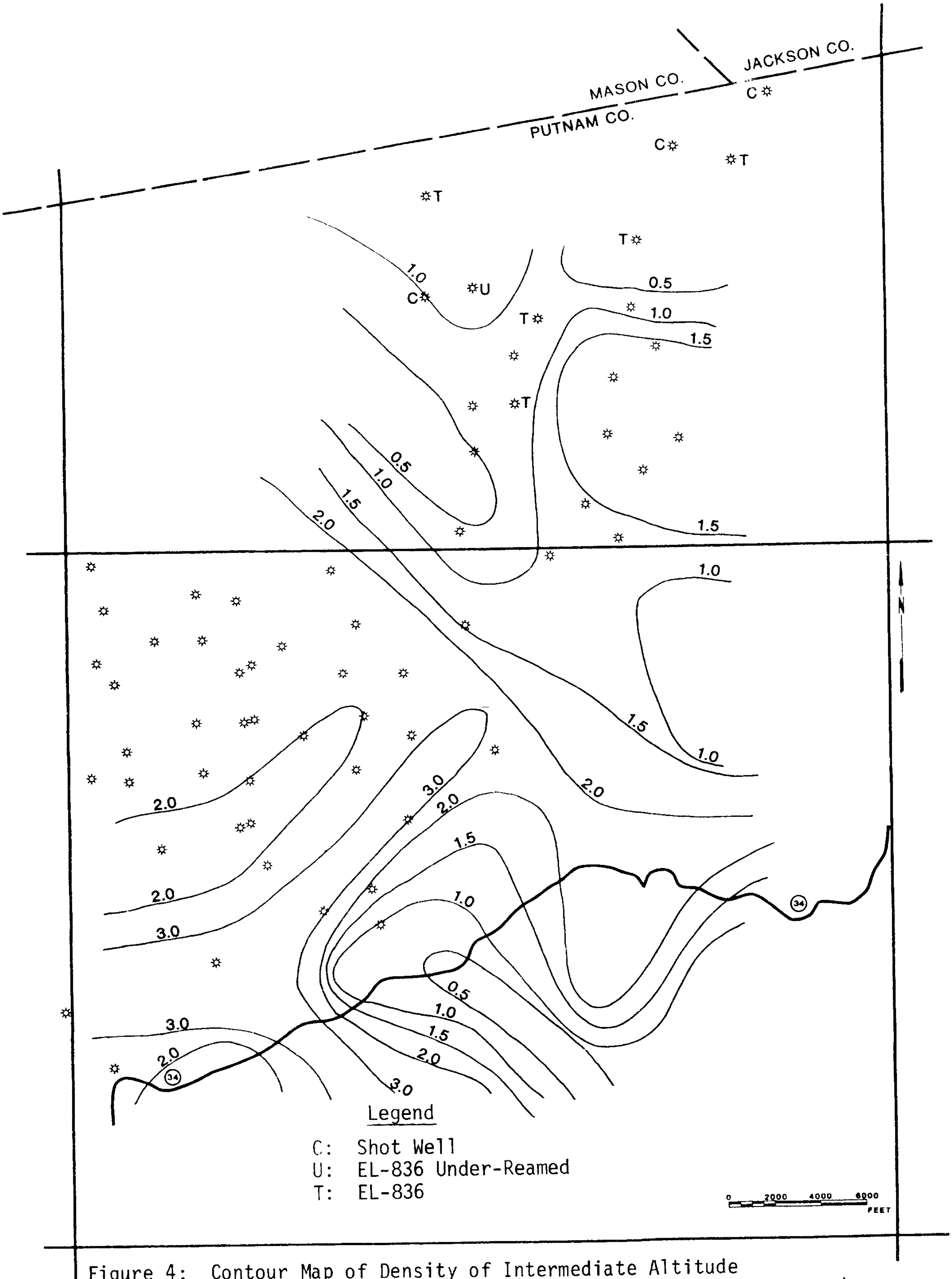


Figure 4: Contour Map of Density of Intermediate Altitude Photolineaments (Miles/Mile^2) (1:86000 scale photography)

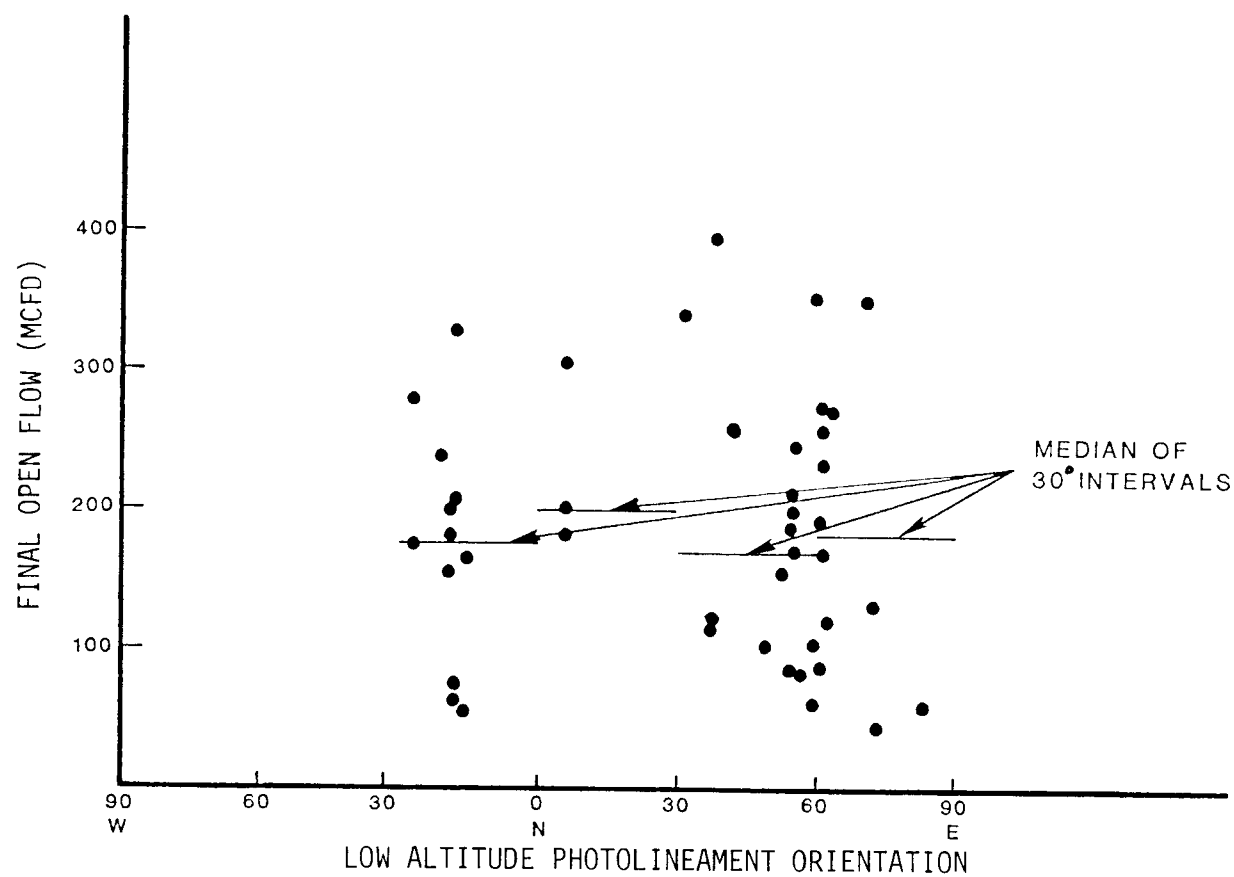


Figure 5: Graph of Final Open Flow Versus Orientation of Nearest Low Altitude Photolineament

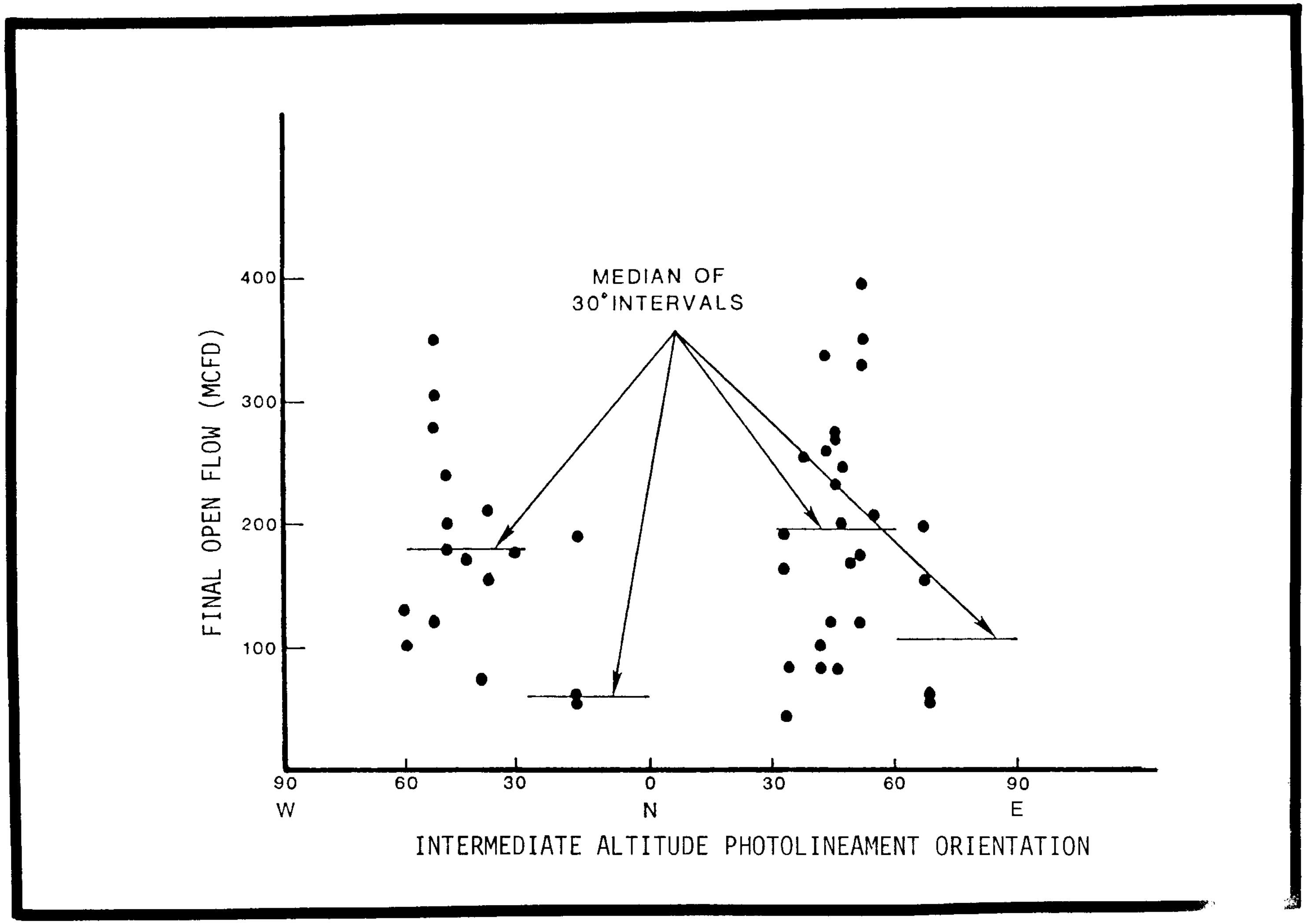


Figure 6: Graph of Final Open Flow Versus Orientation of Nearest Intermediate Altitude Photolineament

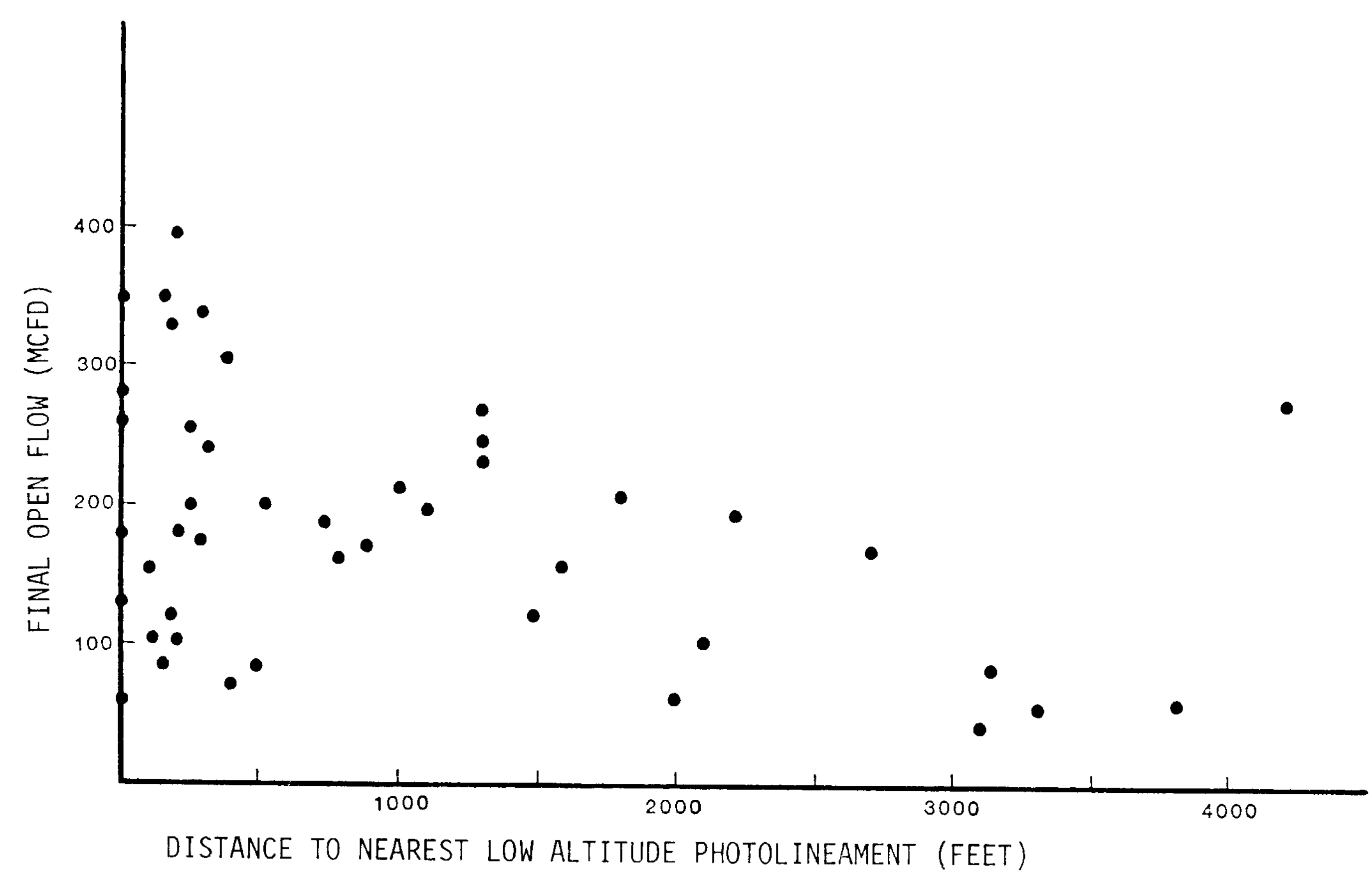


Figure 7: Graph of Final Open Flow Versus Distance to Nearest Low Altitude Photolineament

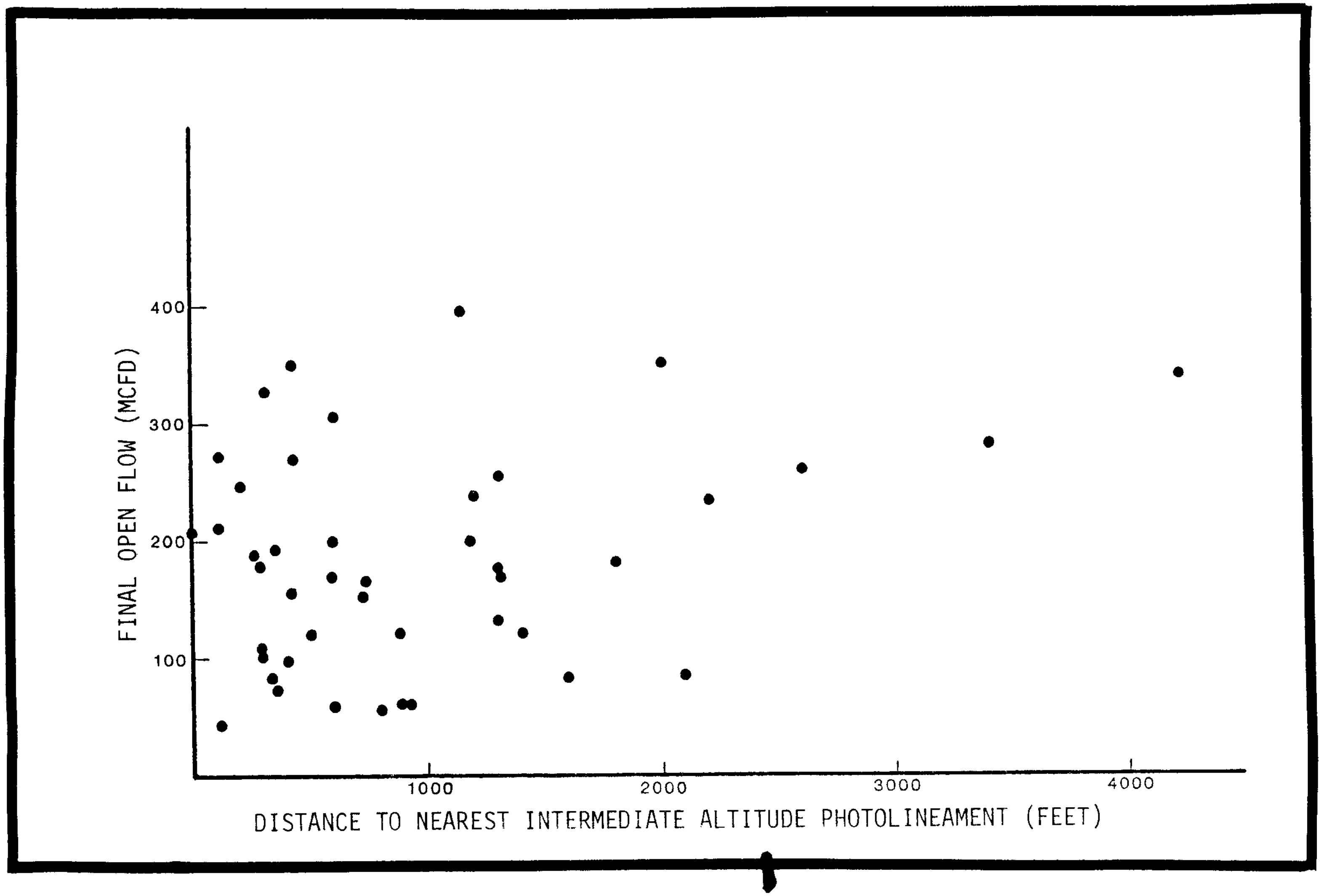


Figure 8: Graph of Final Open Flow Versus Distance to Nearest Intermediate Altitude Photolineament

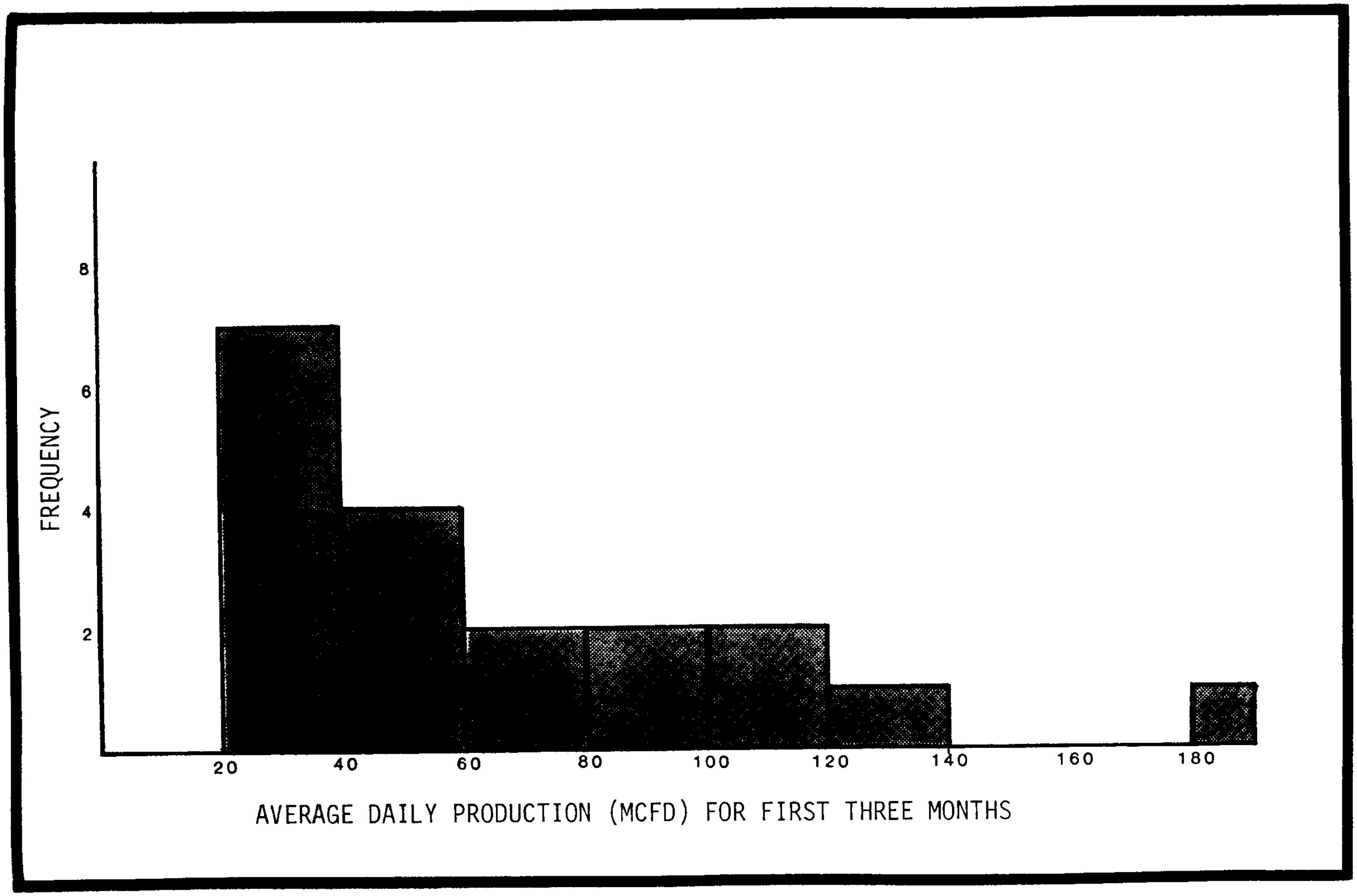


Figure 9: Histogram of Average Daily Production (MCFD)

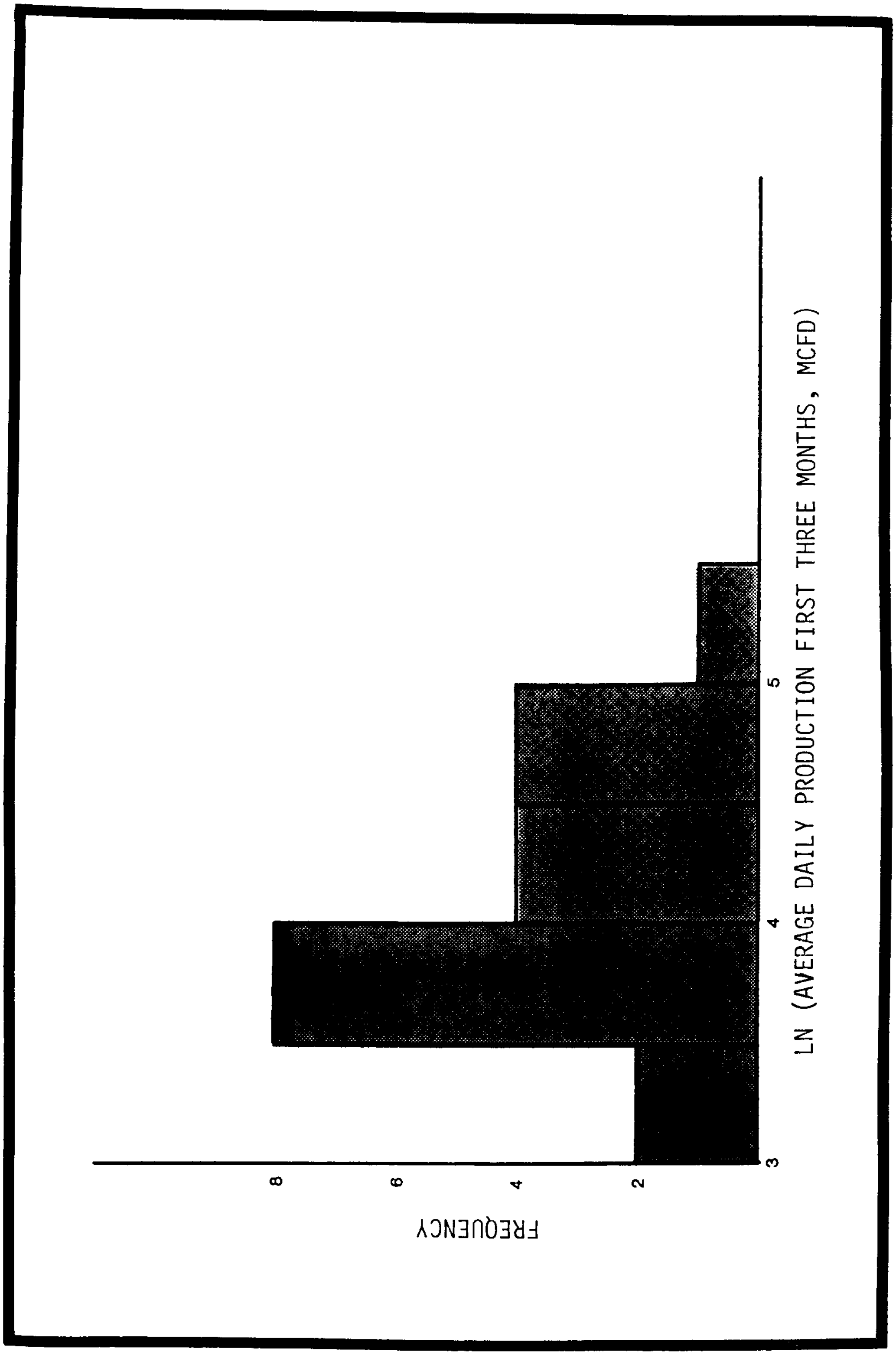


Figure 10: Histogram of Logarithm of Average Daily Production (MCFD)

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980-640-351/089